The use of haptic feedback in Brain-Computer Interfaces and Neurofeedback

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Introduction

Neurofeedback (NF) and brain-computer interfaces (BCI) are based on the recording of the cerebral activity associated with the requested task and the presentation of a feedback. The subject relies on the given feedback (visual, auditory [1] [2] or haptic [3]) to learn and improve his mental strategy. It is therefore of crucial importance that it must be transmitted optimally. Historically, vision is the most used sensory modality in BCI/NF applications, but its use is raising potential issues. The more and more frequent use of haptic as a feedback modality reveals the limits of visual feedback; indeed, a visual feedback is not suitable in some cases, for individuals with an impaired visual system or during a mental motor imagery task (e.g. requiring a great abstraction). In such case, a haptic feedback would seem more appropriate. Haptic feedback has also been reported to be more engaging than visual feedback [4]. This feedback could also contribute to close the sensorimotor loop. Haptic-based BCI/NF is a promising alternative for the design of the feedback and potentially improve the clinical efficacy of NF.

Major haptic-based BCI/NF applications use EEG as imaging modality but the growth in interest of BCI/NF based fMRI raises the question of using a haptic feedback in a MR environment.

The general aim of this survey is to provide a status report regarding advances in haptic-based BCI/NF with a focus on MR-compatible haptic technology. The second goal is to recognize problematics that require further investigation and to recommend directions for future research in this area.

Materials and Methods

We provide an overview of the existing haptic-based BCI/NF systems. Applications related to haptic feedback are multiple: from clinical BCI/NF setting as rehabilitation training in patients with stroke, to entertainment and video games. We reviewed 23 articles are from January 2007 to December 2018.

Results and Conclusions

Since the first haptic BCI/NF study in 2007 by Cincotti [4] and the first pilot study with patients by Buch [5] in 2008, numerous studies haptic-based BCI/NF have been conducted. A critical review of these studies could contribute to gain knowledge and converge on the effectiveness of haptic feedback in general. However, in order to better integrate the use of haptic feedback into BCI/NF studies, changes in the design of these studies and the use of haptic technologies are required.

Since the first integration of a force feedback inside a MR environment, no fMRI-based BCI/NF studies with haptic feedback have been reported.

References

[1] Nijboer F, Furdea A, Gunst I, et al. An auditory brain–computer interface (BCI). Journal of Neuroscience Methods. 2008;167(1):43–50.
[2] Robineau F, Saj A, Neveu R, Van De Ville D, Scharnowski F, Vuilleumier P. Using real-time fMRI neurofeedback to restore right occipital cortex activity in patients with left visuo-spatial neglect: proof-of-principle and preliminary results. Neuropsychological Rehabilitation. 2017:1–22.
[3] Murguialday A. 2007 U. Brain-computer interface for a prosthetic hand using local machine control and haptic feedback. ieeexplore.ieee.org. 2007.
[4] Cincotti F, Kauhanen L, Aloise F, et al. Vibrotactile feedback for brain-computer interface operation. Computational intelligence and neuroscience. 2007;2007:48937.
[5] Buch E, Weber C, Cohen LG, et al. Think to move: a neuromagnetic brain-computer interface (BCI) system for chronic stroke. Stroke. 2008;39(3):910–7.